Claims

1. A thermoelectric element comprising:

a thin film of p-type thermoelectric material,

a thin film of n-type thermoelectric material, and

an electrically insulating substrate,

the thin film of p-type thermoelectric material and the thin film of n-type thermoelectric material being formed on the electrically insulating substrate and being electrically connected,

(i) the p-type thermoelectric material comprising at least one complex oxide selected from the group consisting of:

complex oxides represented by Formula (1): $Ca_aA^1_bCo_cA^2_dO_e$, wherein A^1 is one or more elements selected from the group consisting of Na, K, Li, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Sr, Ba, Al, Bi, Y, and lanthanoids; A^2 is one or more elements selected from the group consisting of Ti, V, Cr, Mn, Fe, Ni, Cu, Ag, Mo, W, Nb, and Ta; $2.2 \leq a \leq 3.6$; $0 \leq b \leq 0.8$; $2.0 \leq c \leq 4.5$; $0 \leq d \leq 2.0$; and $8 \leq e \leq 10$, and

complex oxides represented by Formula (2): $Bi_fPb_gM^1_hCo_iM^2_jO_k$, wherein M^1 is one or more elements selected from the group consisting of Na, K, Li, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Ca, Sr, Ba, Al, Y, and lanthanoids; M^2 is one or more elements selected from the group consisting of Ti, V, Cr, Mn, Fe, Ni, Cu, Ag, Mo, W, Nb, and Ta; $1.8 \leq f \leq 2.2$; $0 \leq g \leq 0.4$; $1.8 \leq h \leq 2.2$; $1.6 \leq i \leq 2.2$; $0 \leq j \leq 0.5$; and $8 \leq k \leq 10$; and

(ii) the n-type thermoelectric material comprising at least one complex oxide selected from the group consisting of:

complex oxides represented by Formula (3): $Ln_mR^1_nNi_pR^2_qO_r$, wherein Ln is one or more elements selected from the group consisting of lanthanoids; R^1 is one or more elements selected from the group consisting of Na, K, Sr, Ca, and Bi; R^2 is one or more elements selected from the group consisting of Ti, V, Cr, Mn, Fe, Co, Cu, Mo, W, Nb, and Ta; $0.5 \leq m \leq 1.7$; $0 \leq n \leq 0.5$; $0.5 \leq p \leq 1.2$; $0 \leq q \leq 0.5$; and $2.7 \leq r \leq 3.3$;

complex oxides represented by Formula (4): $(Ln_sR^3_t)_2Ni_uR^4_vO_w$, wherein Ln is one or more elements selected from the group consisting of lanthanoids; R^3 is one or more elements selected from the group consisting of Na, K, Sr, Ca, and Bi; R^4 is one or more elements selected from the group consisting of Ti, V, Cr, Mn, Fe, Co, Cu, Mo, W, Nb, and Ta; $0.5 \leq s \leq 1.2$; $0 \leq t \leq 0.5$; $0.5 \leq u \leq 1.2$; $0 \leq v \leq 0.5$; and $3.6 \leq w \leq 4.4$;

complex oxides represented by Formula (5): $A_xZn_yO_z$, wherein A is Ga or Al; $0 \leq x \leq 0.1$; $0.9 \leq y \leq 1$; and $0.9 \leq z \leq 1.1$; and

complex oxides represented by Formula (6): $Sn_{xx}In_{yy}O_{zz}$, wherein $0 \leq xx \leq 1$; $0 \leq yy \leq 2$; and $1.9 \leq zz \leq 3$.

2. The thermoelectric element according to Claim 1, wherein

the p-type thermoelectric material comprises at least one complex oxide selected from the group consisting of complex oxides represented by the formula: $Ca_aA^1_bCo_4O_e$, wherein A^1 is one or more elements selected from the group consisting of Na, K, Li, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Sr, Ba, Al, Bi, Y, and lanthanoids; $2.2 \leq a \leq 3.6$; $0 \leq b \leq 0.8$; and $8 \leq e \leq 10$, and complex oxides represented by the formula: $Bi_fPb_gM^1_hCo_2O_k$, wherein M^1 is one or more elements selected from the group consisting of Sr, Ca, and Ba; $1.8 \leq f \leq 2.2$; $0 \leq g \leq 0.4$; $1.8 \leq h \leq 2.2$; and $8 \leq k \leq 10$;

the n-type thermoelectric material comprises at least one complex oxide selected from the group consisting of complex oxides represented by the formula: $Ln_mR^1_nNiO_r$, wherein Ln is lanthanoid; R^1 is one or more elements selected from the group consisting of Na, K, Sr, Ca, and Bi; $0.5 \leq m \leq 1.2$; $0 \leq n \leq 0.5$; and $2.7 \leq r \leq 3.3$, complex oxides represented by the formula: $(Ln_sR^3_t)_2NiO_w$, wherein Ln is lanthanoid; R^3 is one or more elements selected from the group consisting of Na, K, Sr, Ca, and Bi; $0.5 \leq s \leq 1.2$; $0 \leq t \leq 0.5$; and $3.6 \leq w \leq 4.4$, and complex oxides represented by the formula: $Ln_xR^5_yNi_pR^6_{q'}O_{r'}$, wherein Ln is lanthanoid; R^5 is one or more elements selected from the group

consisting of Na, K, Sr, Ca, Bi, and Nd; and R^6 is one or more elements selected from the group consisting of Ti, V, Cr, Mn, Fe, Co, and Cu; $0.5 \leq x \leq 1.2$; $0 \leq y \leq 0.5$; $0.5 \leq p \leq 1.2$; $0.01 \leq q' \leq 0.5$; and $2.8 \leq r' \leq 3.2$.

3. The thermoelectric element according to Claim 1, wherein the thin film of p-type thermoelectric material and the thin film of n-type thermoelectric material are electrically connected by one of the following methods:

bringing one end portion of the thin film of p-type thermoelectric material into direct contact with one end portion of the thin film of n-type thermoelectric material;

bringing one end portion of the thin film of p-type thermoelectric material into contact with one end portion of the thin film of n-type thermoelectric material via an electrically conductive material;

bringing one end portion of the thin film of p-type thermoelectric material into direct contact with one end portion of the thin film of n-type thermoelectric material and covering the contact portion with an electrically conductive material.

4. The thermoelectric element according to Claim 1, wherein the thin film of p-type thermoelectric material and the thin film of n-type thermoelectric material are formed on the same surface or on different surfaces of the electrically insulating substrate.

5. The thermoelectric element according to Claim 1, wherein the electrically insulating substrate is a substrate comprising a plastic material.

6. The thermoelectric element according to Claim 1, wherein thermoelectromotive force is at least 60 μV/K in a temperature range of 293 K to 1073 K.

7. The thermoelectric element according to Claim 1, wherein

electrical resistance is 1 KΩ or lower in a temperature range of 293 K to 1073 K.

8. A thermoelectric module comprising a plurality of the thermoelectric elements of Claim 1, wherein the thermoelectric elements are electrically connected in series such that an unconnected end portion of a p-type thermoelectric material of one thermoelectric element is electrically connected to an unconnected end portion of an n-type thermoelectric material of another thermoelectric element.

9. A thermoelectric conversion method comprising positioning one end of the thermoelectric module of Claim 8 at a high-temperature portion and positioning the other end of the module at a low-temperature portion.